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A discussion on recent developments in Turkey's emerging solar power market

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ABSTRACT

Market reform, energy security and environmental protection are three primary energy policy goals of Turkish government. Although Turkey's abundant solar energy resources can directly address the government's energy policy goals, Turkey has not utilized solar power yet. Utilization of country's huge solar energy potential would decrease dependence on imported fossil fuels and contribute to fulfill environmental commitments. However, lack of regulatory and financial support for the development of solar power has considerably delayed the utilization of country's huge solar potential. The government has taken only modest steps to promote investment in solar power until the end of 2010 when a new feed-in tariff policy was adapted. Turkey's solar energy potential, PV technology status and prospect for concentrating solar power in Turkey have been explored in a number of studies; yet literature dealing with recent policy developments, associated investment environment and opportunities for solar power investors are limited. The aim of this paper is to set out the latest legal framework for investment in Turkey's emerging solar power market and to provide some guidelines to potential investors who appreciated country's huge solar energy potential.

Contents

1. Introduction

Energy is a key global issue since social, economic and environmental development of countries is directly related with the availability of energy. In 2010, world primary energy consumption was 12,002 million tons of oil equivalents (Mtoe), of which 87% was provided by fossil fuels. Nuclear energy provided 5.2% while renewables including hydropower provided 7.8% of global primary energy consumption in 2010. World primary energy consumption grew by 5.6% in 2010, the largest increase (in percentage terms) since 1973 [1], and it is projected to grow by 1.6% per annum over the period 2010–2030, adding 39% to global consumption by 2030 [2]. Fossil fuels will continue to dominate global energy mix, but growth of global energy consumption will be increasingly met by non-fossil fuels; renewables, nuclear and hydro together accounting for 34% of the growth. Gas and non-fossil fuels gain share in

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global energy mix at the expense of coal and oil. The fastest growing fuels are renewables (including biofuels) which are expected to grow at 8.2% per annum 2010–2030; among fossil fuels, gas grows the fastest (2.1% per annum) and oil the slowest (0.7% per annm) [3].

Although fossil fuels have been the most dominant energy resource in meeting global energy demand for decades, it has been recognized that these critical energy resources have severe impacts on climate change and they are ultimately finite. Widespread and increasing use of fossil fuels in energy production is considered as the largest source of anthropogenic carbon dioxide (CO_2) emissions, which is largely blamed for global warming and climate change [4]. Climate change manifests in higher average global temperatures, rising global mean sea levels, melting ice caps and an increased intensity and frequency of extreme weather events [5]. Climate change severely affects the basic elements of life for people around the world – access to water, food production, health, and the environment. Strong and early action is needed in order to avoid severe impacts of climate change on human wellbeing. [6].

Dramatic increase in fossil fuel prices, finite nature of fossil energy sources, increasing concerns regarding environmental impact, especially related to CO_2 emissions, and health and safety considerations are forcing the search for new alternative energy sources [7]. In recent years, renewable energy resources have emerged as key element in challenging the abovementioned fossil fuel related concerns and in meeting growing global energy demand in a sustainable manner. In order to accelerate the deployment of renewable energy resources, a variety of policies like feed-in-tariff (FiT), portfolio standard (RPS), tax credits, pricing laws, production incentives, quota requirements, and trading systems have been developed and implemented in many countries [8]. Solar energy is one of the most cleanest and abundant energy resource on earth. It does not deplete natural resources, does not cause CO_2 or other gaseous emission into air or generates liquid or solid waste products [9]. Solar energy that hits the earth's surface in 1 h is about same as the amount consumed by all human activities in a year [10]. Solar energy contributes diversification and security of energy supplies, increase regional/national energy independence, allows reclamation of degraded land and electrification of rural and remote communities [9]. It also contributes to national employment and job creation. Compared to fossil-fuel power plants, renewable energy generates more jobs per unit of installed capacity, per unit of power generated and per dollar invested. Solar photovoltaic (PV) has the highest average job multiplier with a large gap between it and the next highest renewable technologies (geothermal and solar thermal) [11].

Although a number of technical, financial, regulatory and institutional barriers still exists for large-scale deployment of solar energy in national energy systems, solar energy has experienced significant growth over the last decade due to both technological improvements resulting in cost reductions and supportive government policies [12]. Availability, current status, strategies, government policies, major achievements and future potential of solar energy options for different countries have been addressed in numerous studies [13–18].

Turkey is an energy importing country with significantly high dependence on imported fossil fuels. High dependence on imports for energy poses significant risk for country's social, economic and environmental development. On the other hand, there is good potential for PV applications in the local market since the country is enormously suitable due to high rates of solar radiation and available land for PV applications [19]. In addition to supplying country's growing energy demand, solar energy can enable the country to achieve the twin goals of reducing carbon emissions and increasing energy security. Due to lack of regulatory and financial support, utilization of solar energy have been delayed until the end of 2010 when government adopted a new policy in order to promote investment in solar power. Turkey's solar energy potential, PV technology status and prospect for concentrating solar power in Turkey have been explored in a number of studies [20,21]; yet literature dealing with recent policy developments, associated investment environment and opportunities for solar power investors are limited.

The aim of this paper is to set out the latest legal framework for investment in Turkey's emerging solar power market and to provide guidelines to potential investors who appreciated country's huge solar energy potential. The paper is organized as follows. Section 2 briefly describes current status of solar power in the world and in Turkey. Section 3 provides an overview of Turkey's energy profile. Section 4 describes solar energy potential of Turkey while current Turkish legislation on solar energy is presented in Section 5. A critical evaluation of solar energy incentives is presented in Section 6. Some guidelines for investors are provided in Section 7. Finally, conclusions are drawn in Section 8.

2. Solar power in the world and in Turkey

Solar energy can be harnessed by three solar technologies. Solar phovoltaics (PV) generate electricity through direct conversion of sunlight with semi-conductor metarials. Concentrating solar power (CSP) systems use concentrated solar radiation to heat a receiver to high temperature, then heat is transformed into mechanical energy by turbines or engines and then into electricity [22]. Solar heating and cooling (SHC) uses the thermal energy directly from the sun to heat or cool domestic water or building spaces [10]. CSP systems use direct normal irradiance which is the energy received on a surface tracked perpendicular to the sun's rays. Therefore, CSP requires reliably clear skies which are usually found in arid and semi-arid areas. PV has a competitive advantage since it can use both direct and diffuse irradiance [22].

In the last decade, supportive solar policies have significantly expanded the utilization of solar energy in power generation. The feed-in-tariff (FiT) policy has proven to be one of the most effective mechanism that encourages the deployment of solar power. Germany is the first country to introduce a solar FiT and has become the world leader in terms of both installed PV capacity and solar industry. The success of Germany gave momentum to many other countries. Globally, more than 40 countries have adopted some type of FiT system in order to harness their solar potential. The installed solar power capacity has increased considerably in many of these countries after the introduction of FiT policy [23]. As a result of policy support and associated cost reductions, PV market has experienced a rapid growth from 1.5 GW in 2000 to 39.5 GW in 2010, i.e. an average annual growth rate of 40%. In 2010, global installed PV capacity was 39.5 GW, producing about 50 TWh of electricity every year. The European Union (EU) was the world's largest PV market with total installed PV capacity of 29.2 GW in 2010. Germany represents 59% of EU PV market, followed by Spain (13%) and Italy (12%). PV installations in EU produce 35 TWh of electricity every year, supplying 1.2% of EU's electricity demand. Germany accounts for 43% of global installed PV capacity, followed by Japan (9%) and the USA (6%). Table 1 provides worldwide installed PV capacity in 2010 [24]. Global PV capacity is estimated at 345–688 GW by 2020, supplying 12% of EU's electricity demand and 4% global electricity demand [23]. In 2010, global installed CSP capacity was 1327 MW [25]. CSP projects in development or under construction in countries including China, India, Morocco, Spain and the USA are expected to total 15 GW [22].

In Turkey, solar energy has been mainly used for heating water. Currently, roof-top solar panel installations used for heating water is roughly 12 million m^2 [26]. With approximately 8 GW_{th} installed capacity, Turkey ranks third in the world after China and the

Table 1
Global installed PV capacity in 2010.

Country	PV capacity (MW)	Country	PV capacity (MW)
EU		North America	
Austria	103	Canada	200
Belgium	803	USA	2528
Bulgaria	18		
Czech Republic	1953	APEC	
France	1025	Australia	504
Germany	17,193	South Korea	655
Greece	206	Taiwan	22
Italy	3494	Thailand	10
Portugal	130		
Slovakia	145	Japan	3622
Spain	3784	China	893
United Kingdom	66	India	102
Rest of the EU	333	Rest of the world	1742
EU total	29,253	World total	39,531

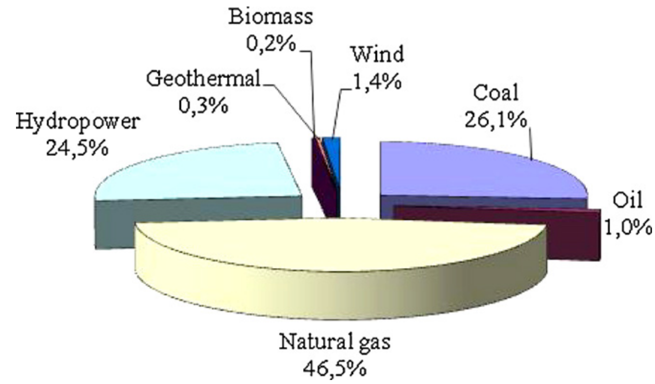


Fig. 1. Share of primary energy sources in total electricity generation (2010).

USA at hot water heating systems [27]. Despite high dependence on imports for energy resources and huge solar energy potential, Turkey has not utilized solar power yet except demonstration projects and research purposes. Some public bodies use PV systems in supplying remote electricity demand such as telecom stations, highway signaling, forest monitoring towers, meteorological stations, and fire observation stations [26]. Total installed PV capacity is estimated to be 4–5 MWp in Turkey [28].

Turkish government's electricity market and security of supply strategy addresses the issues of energy security, climate change mitigation and sustainable development and emphasizes the priority of domestic and renewable resources in supplying country's growing electricity demand. The strategy sets the target of achieving at least 30% of electricity generation from renewables by 2023. This target is aimed to be achieved mostly through the deployment of all technically and economically available hydropower sources, increasing installed wind power capacity to 20 GW (up from 792 MW in 2009) and geothermal generation capacity to 600 MW (up from 77 MW in 2009) until 2023. However, there is no official target for electricity generation from solar energy. The Strategy only indicates the goal of making solar energy a widely used option in electricity generation by following developments in solar power technology and introducing incentive mechanisms through making necessary revisions in the related laws [29]. The European Photovoltaic Industries Associtaion (EPIA) projects Turkey's installed PV capacity to be 20 GWp by 2020 [30]. Turkish Phovoltaic Technology Platform (UFTP) has a target of 6 GWp with a moderate scenario and 10 GWp with a policy driven scenario by 2020 [31].

3. Turkey's energy outlook

Turkey has one of the fastest growing economies in the world. In 2010, Turkey was the 16th largest economy in the world and the 6th largest economy in Europe [32]. A strong growth was observed in Turkish economy between 2002 and 2007 with an average annual Gross Domestic Product (GDP) growth rate of 7.4% although GDP growth slowed in 2008 and 2009 due to global financial crisis that affected many economies. With recovery after recession, Turkish economy grew by 8.9% in 2010 [33]. Turkish government has GDP growth targets of 4.5% in 2011, 5.0% in 2012 and 5.5% in 2013 [34].

Turkey's energy consumption shows a trend in parallel with economic growth. Primary energy consumption increased at an average annual rate of 6% over 2002–2007 to pace with economic growth while energy consumption reduced since 2008 due to economic slowdown. With economic recovery, primary energy consumption increased by 9.8% in 2010 with respect to 2009 levels, which is significantly higher than global increase of 5.6% and increase of 3.5% in OECD countries [1].

In 2009, Turkey's total primary energy supply (TPES) and total final consumption (TFC) were 97.6 Mtoe and 73.1 Mtoe, respectively. Turkey is an energy importing country since about 77.5% of TPES was provided by imports in 2009. Fossil fuels accounted for 90.6% of TPES in 2009 while renewable sources collectively provided the remaining. In 2009, the share of energy sources in TPES was as follows: natural gas (29.6%), oil (29.8%), coal (30.5%), waste (4.8%), hydropower (3.1%) and geothermal/solar/wind (2.2%) [35].

In parallel with economic growth, Turkey has a fast growing electricity market with an average annual demand increase of about 6–9% over the last two decades [36]. Installed capacity more than doubled while electricity generation more than tripled in the last two decades to pace with increasing demand [36,37]. In 2010, Turkey's total electricity production was 212.2 TWh, 73.6% of which was produced from thermal power plants, 24.5% from hydropower plants and 1.9% from renewable sources such as wind, geothermal and biomass. The share of primary energy sources in total electricity production is presented in Fig. 1 [38]. Turkey's total installed capacity reached to 49.5 GW by the end of 2010, an increase of 81% over 2000. In 2010, the share of natural gas power plants in installed capacity was 37.6%, followed by hydropower (32.0%), coal (24.1%), oil (3.2%), wind (2.7%) and biomass and geothermal (0.4%) [36,37]. Turkey has not utilized nuclear and solar power yet.

Turkey's energy use is expected to roughly double over the next decade due to increasing population, fast growing urbanization and industrialization [39]. The official electricity demand projections estimate Turkey's electricity demand to be about 390 TWh by 2019 (with an average annual increase of about 7%), almost twice of current demand [40].

4. Solar energy potential of Turkey

Turkey has a high potential for solar energy due to its advantegous geographical position. Based on data measured by the Turkish State Meteorological Service (TSMS) during 1966–1982, General Directorate of Electrical Power Resources Survey and Development Administration (EIE)[2] made the first solar energy potential evaluation of Turkey. That evaluation revealed that Turkey has average annual total insolation duration of 2640 h (7.2 h/day) and average annual solar radiation of 1311 kWh/m^2-year (3.6 kWh/m^2-day) [41]. Later on, TSMS modeled Turkey's solar energy potential using insolation duration and radiation data measured by 157 weather stations of TSMS

[2] The General Directorate of Electrical Power Resources Survey and Development Administration is responsible for surveys and research on renewable energy sources.

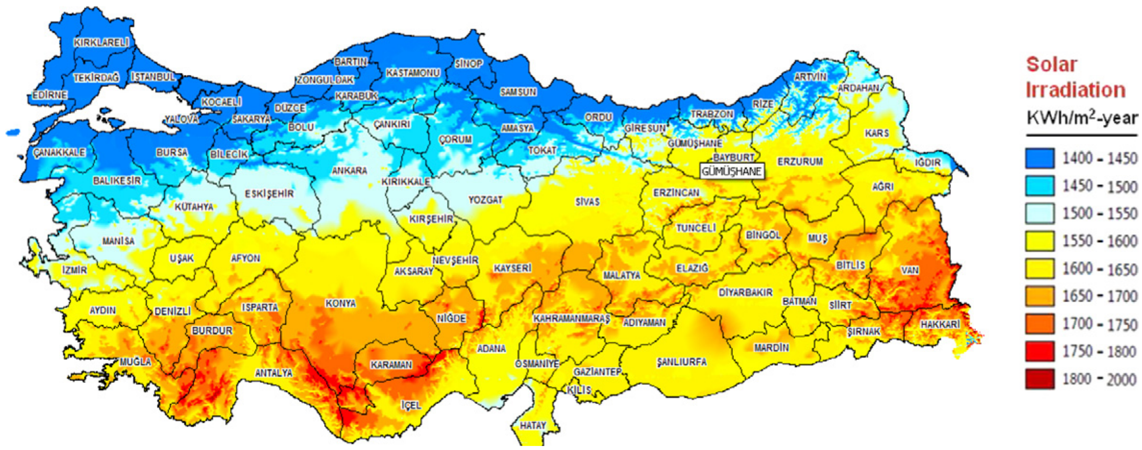


Fig. 2. Solar energy potential atlas of Turkey (SEPA).

during 1971 and 2000. According to TSMS modeling, Turkey's average annual total insolation duration is 2573 h (7 h/day) and average annual total radiation is 1474 kWh/m^2-year (4 kWh/m^2-day). Tables 2 and 3 show monthly and regional solar energy potential of Turkey determined by TSMS, respectively [42].

Finally, in 2010, EIE published the Solar Energy Potential Atlas of Turkey (SEPA), a major development for feasibility studies of solar power investors (Fig. 2). The ESRI Solar Radiation Model which combines solar radiation, topography and seasonal data of the location was used to develop SEPA. Long term data measured by 148 stations of TSMS and 8 stations of EIE during 1985 and 2006 were used to calculate model parameters and calibrate the model. SEPA revealed that Turkey has average annual total insolation duration of 2738 h (7.5 h/day) and average annual solar radiation of 1527 kWh/m^2-year (4.2 kWh/m^2-day) [43]. SEPA provides monthly variation of average daily insolation duration and solar radiation level for all cities and counties of cities throughout Turkey. Depending on PV type and area, the amount of solar energy that can be produced is also provided by SEPA.

As it can be seen in Fig. 2, Turkey's annual solar radiation level changes between 1400 kWh/m^2-year in the Black Sea region and 2000 kWh/m^2-year in the South East and the Mediterranean regions. Compared to Europe with average solar energy of 1200 kWh/m^2-year and the Middle East with average solar energy of 1800–2300 kWh/m^2-year [23], Turkey offers one of the best locations for solar power generation in the world. Figs. 3 and 4 show monthly variation of average daily solar radiation and insolation duration in Turkey [43]. Using SEPA and PV technology, Turkey has a technical solar power generation capacity of 380 TWh/year, corresponding to 56 GWp of gas powered stations [28].

Table 2
Monthly average solar energy potential of Turkey.

Month	Monthly total solar radiation (kWh/m^2-month)	Sunshine duration (h/month)
January	59.7	106.9
February	76.6	135.2
March	116.8	170.2
April	139.1	203.5
May	171.5	260.5
June	186.9	318.1
July	193.4	339.3
August	174.8	322.3
September	140.3	277.9
October	100.0	200.6
November	64.7	142.0
December	50.0	96.3
Total	1473.8	2572.8
Average	4 kWh/m^2-day	7 h/day

Table 3
Regional solar energy potential of Turkey.

Region	Monthly total solar radiation (kWh/m^2-month)	Sunshine duration (h/month)
Southeastern Anatolia	1648	2845
Mediterranean	1548	2737
East Anatolia	1523	2519
Central Anatolia	1481	2563
Aegean	1528	2615
Marmara	1329	2250
Black Sea	1305	1929

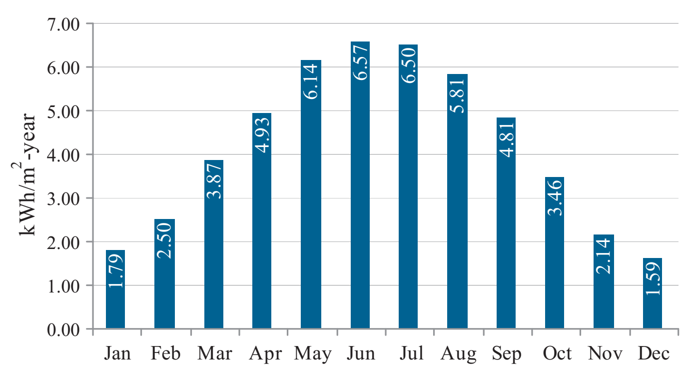


Fig. 3. Monthly variation of average daily solar radiation.

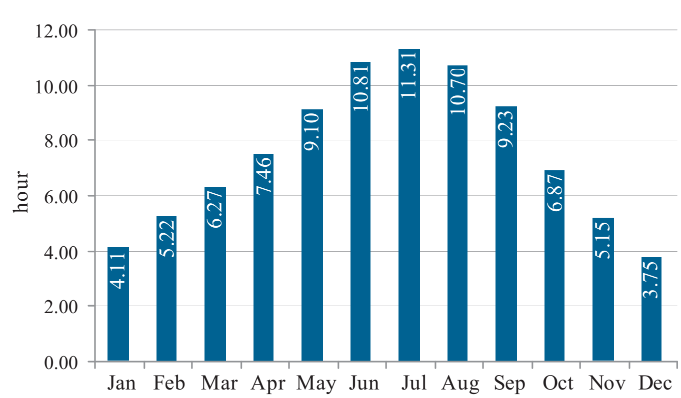


Fig. 4. Monthly variation of average daily insolation duration.

5. Current Turkish legislation on solar energy

Turkey does not have a separate legislation that governs electricity generation from solar energy. In legislative terms, the utilization of solar energy in electricity generation and incentives to encourage investment in solar power are generally considered together with other renewable energy resources. The Electricity Market License Regulation and the Renewable Energy Law with its subsequent amendments set the legal framework for electricity generation from renewables including solar energy.

5.1. Electricity Market License Regulation

The Electricity Market License Regulation ("License Regulation")[3] is the first piece of legislation that promotes power generation from renewables. The License Regulation sets out the first incentives to encourage private investment in renewable based power generation including solar power. The License Regulation provides following incentives:

(i) *Reduced license fee:* Renewable based power plants are required to pay only 1% of total license fee during license application and are exempted from annual license fee during the first eight years of operation based on the commissioning date indicated on their licenses.

(ii) *Connection priority:* The Turkish Electricity Transmission Company (TEIAS) and/or distribution companies are obliged to give priority to renewable based generation facilities for network connection

(iii) *Purchase obligation:* Retail sale license holders are obliged to purchase electrical energy primarily from renewable based power plants in order to supply their eligible customers whenever the price of renewable based electrical energy is lower than and/or equal to the Turkish Electricity Trade and Contracting Corporation (TETAS) tariff and there is no cheaper supply opportunity in the market.

(iv) *Exemption from licensing and company establishment obligation:* In 2008, renewable based power plants or microgeneration facilities with installed capacity of less than 500 kW were exempted from licensing and company establishment obligations. These generators are referred to as "*exempted generators*". The technical and financial principles for the surplus electricity exported to grid by "exempted generators" are regulated by the Regulation Regarding Unlicensed Power Generation in relation to the Electricity Market[4].

5.2. Renewable Energy Law

In order to provide additional incentives to renewable based power generation, the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy ("Renewable Energy Law No. 5346") was enacted on 18 May 2005. Renewable Energy Law No. 5346 has the purpose of expanding the utilization of renewable sources for generating electricity in a dependable and economic manner, increasing diversification of energy resources, protecting environment and developing related manufacturing sector for the realization of these objectives. The law covers solar, wind, geothermal, biomass, biogas, wave, current, tidal energy and hydraulic resources either canal or run of river type or with a reservoir area of less than 15 km^2. In 2007, some of the incentives provided by the Renewable Energy Law No. 5346 was amended by the Energy Efficiency Law No. 5627. Table 4 presents the incentives provided by the Renewable Energy Law No. 5346 and changes introduced by the amendment.

The feed-in-tariff (FiT) introduced by the Renewable Energy Law No. 5346 did not trigger the deployment of solar power generation. The tariff was set equal to all forms of renewable technology without considering the associated generation costs for different renewable technologies. The FiT of Turkish average wholesale price of the previous year (TORETOSAF in Turkish) limited to Turkish lira equivalent of 5–5.5 €cent/kWh was not profitable enough for less mature renewable technologies, particularly for solar energy. The uncompetitive FiT set by the Turkish government has discouraged investors and delayed the utilization of country's huge solar potential. Solar investors has always asked for a favourable and guaranteed tariff in order to secure their investment while the government has considered the FiT as a burden on budget. Finally, after long discussions between government and industry and delays due to global financial crisis, the government took a more serious step at the end of 2010 and introduced new supporting mechanisms to harvest the country's huge solar energy potential.

5.3. Amended Renewable Energy Law

In December 2010, the Renewable Energy Law No. 5346 was amended by Law No. 6094 (hereinafter "Amendment Law")[5] in order to improve renewable energy incentives and boost renewable energy investment in Turkey. The Amendment Law introduced following incentives:

(i) *Feed-in tariffs:* The Amendment Law introduced different FiTs for different renewable energy technologies. The new FiTs are applicable to renewable energy generation license holders subjected to Renewable Energy Resource (RER) Support Mechanism and that have commenced/will commence operations between 18 May 2005 and 31 December 2015. For generators commissioned after 31 December 2015, the FiTs will be determined by the Council of Ministers provided that they will not exceed the rates determined by the Amendment Law. A generation license holder within the scope of the RER Support Mechanism can benefit from new FiTs for a period of ten years starting from its commissioning date. The new FiTs for different renewable energy technologies are given in Table 5.

"*Exempted generators*" can also benefit from the FiTs given in Table 5 for the surplus energy exported to the distribution grid. They can benefit from FiTs for a period of 10 years starting from the commissioning date of the facility and are required to sell the surplus production to the distribution company holding retail sale licence within their distribution region. The electrical energy purchased by distribution companies in that way is deemed to be generated and given to the network by that distribution company within the scope of RER Support Mechanism.

(ii) *Additional incentives for domestically manufactured components:* In order to promote the use of domestically manufactured equipment and support domestic renewable industry, the Amendment Law introduced additional incentives if mechanical and/or electromechanical components of renewable based power plants are manufactured in Turkey. Such generators can benefit from additional incentives for each domestic component used for a period of 5 years starting from their

[3] The Electricity Market License Regulation, published in the Official Gazette Date: 4 March 2002 No: 24836.

[4] The Regulation Regarding Unlicensed Power Generation in relation to the Electricity Market, published in the Official Gazette Date: 21 July 2011 No: 28001.

[5] The Law Amending the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy, Law No. 6094 enacted on 29 December 2010, published in the Official Gazette Date: 8 January 2011 No: 27809.

Table 4
Renewable incentives provided by Law No. 5346 and Law No. 5627.

Incentive type	Renewable Energy Law No. 5346	Amendment by Energy Efficiency Law No. 5627
Purchase obligation	Obligation on retail sale license holders to purchase electrical energy from renewable energy certified plants in proportion to their share in domestic market in the previous year	Same as Law No. 5346
	Annual publication of the amount of renewable energy certified electrical energy by EMRA. In case there is sufficient renewable energy certified electrical energy within the market, the purchase obligation ratio must be at least 8% of sales in the previous year	At least 8% purchase obligation ratio was abolished
	Exemption of public distribution companies holding a retail sale license from purchase obligation until 1 January 2007	Same as Law No. 5346
	Also allowed to sell in the spot market or via bilateral agreements with eligible customers	Same as Law No. 5346
Feed-in tariff	The average wholesale electricity price of the previous year determined by the EMRA	The average wholesale price of the previous year determined by EMRA and limited to the Turkish lira equivalent to 5–5.5 €cent/kWh
	The authorization of the Council of Ministers to increase this price up to 20% at the beginning of each year	The authorization was abolished
	Valid until the end of 2011 and for RER certified generators that have been operation for seven years or less	Valid for renewable energy certified generators that are commissioned before 2013 and have been operation for ten years or less
Reduced fees for land acquisition	50% discount on permission, rent, right of access and land use fees in case the land owned by the General Directorate of Forestry or the Treasury is used	The discount rate was increased to 85% and was also applied to land and system use fees for power lines between transportation roads and system connection points
	Discount applicable during investment period	Discount applicable for the first 10 years, including investment and operation period and for renewable based generators commissioned until the end of 2011
Other incentives	Exemption from the fees charged for the development of woodland villages, promotion of forestation and erosion mitigation	
	Eligibility of investment in generation facilities, procurement of domestically manufactured electromechanical systems, investment on research, development and manufacturing regarding solar cells and concentrated collectors, investment on research and development concerning biomass to benefit from the incentives determined by the Council of Ministers	Same as Law No. 5346
	Ban on the creation of development plan on public land that may have negative impact on the use and efficiency of renewable energy resources	Same as Law No. 5346

Table 5
Turkish feed-in tariffs for renewable based power generation.

Generation type	Feed-in tariff ($cent/kWh)
Hydropower	7.3
Wind	7.3
Geothermal	10.5
Biomass (including landfill gas)	13.3
Solar	13.3

commissioning date provided that the generators are subjected to the RER Support Mechanism and commissioned before 31 December 2015. For generators commissioned after 31 December 2015, additional incentives for domestic components will be determined by the Council of Ministers. "*Exempted generators*" are also eligible to benefit from these additional incentives under the same conditions. Additional incentives for domestically manufactured components for solar power is given in Table 6.

As required by the Amendment Law, the Ministry published a regulation which sets out principles and procedures related to standards, certification and inspection of domestically manufactured components[6]. According to the regulation, component or system supplier is required to obtain "Manufacture Status Document"[7] and "Manufacture Certificate"[8] from relevant authorities and submit these documents to renewable generation license holder who purchases the components. Then, the license holder is obliged to submit these documents to the Ministry or to the institution authorized by the Ministry in order to be able to benefit from the local component bonus. During the provisional acceptance of a renewable based power plant, a commission composed by Ministry authorities, representatives of the license holder and constructor of the plant is required to control whether domestically manufactured components used in the plant have "Manufacture Status Document". Within 15 days following the control, the Ministry is required to inform EMRA on the bonus tariff to be applied to the license holder.

(iii) *Renewable Energy Resource (RER) Support Mechanism:* The Amendment Law established the RER Support Mechanism through which renewable power plants sell their output and FiTs are paid to these power plants. In order to benefit from

[6] The Regulation Regarding Local Manufacture of the Components Used in the Generation of Electricity from Renewable Energy Resources, published in the Official Gazette Date: 19 June 2011 No: 27969.

[7] "Manufacture Statement Document" shows that the component is manufactured in Turkey. It must be prepared a certified public accountant and certified by the Chamber of Industry and/or Chamber of Commerce and Industry with which the system supplier or component supplier is affiliated. The document is valid for five years following the issuing date.

[8] "Manufacture Certificate" shows that the component is compatible with national or international standards. It must be prepared by an international accrediting agency which signed a mutual recognition agreement with International Accreditation Forum (IAF) according to the TS EN 45011 Ğeneral Standards for the Certification Institutions which Perform Product Certification.

Table 6
Additional solar power incentives for domestic components.

Generation type	Domestic component	Additional incentive ($cent/kWh)
Photovoltaic solar power	PV panel integration and solar structural mechanics production	0.8
	PV modules	1.3
	Cells forming the PV modules	3.5
	Inverter	0.6
	Material focusing the solar rays onto the PV module	0.5
Intensified solar power	Radiation collection tube	2.4
	Reflective surface plate	0.6
	Sun chasing system	0.6
	Mechanical accessories of heat energy storage system	1.3
	Mechanical accessories of steam production system that colleccts the sun rays on the tower	2.4
	Stirling engine	1.3
	Panel integration and solar panel structural mechanics	0.6

new FiTs, both licensed and "*exempted generators*" are required to participate into the RER Support Mechanism. The mechanism operates on a calendar year basis. Renewable energy generation license holders who wish to participate into the mechanism in the next calender year are required to obtain a RER Certificate from EMRA and apply to EMRA until 31st October every year. After evaluation, EMRA is required to publish the list of renewable generation license holders subject to the RER Support Mechanism until 30th November. Renewable based generation license holders subject to RER Support Mechanism cannot leave the mechanism in the year they are included. Thereafter, they can leave the mechanism and sell their electricity via bilateral contracts or in the balancing and settlement market. The Amendment Law also obliges "*exempted generators*" to participate into the RER Support Mechanism for the surplus energy exported to grid through distribution companies having retail sale license. In order to include this surplus energy to the RER Support Mechanism, the distribution companies are required to apply to EMRA until 31st October every year on behalf of exempted generation within their distribution region. "*Exempted generators*" can never leave the mechanism as the mechanism is the only way for them to collect revenue for the surplus energy exported to the grid.

As required by the Amendment Law, EMRA published a regulation which sets out the operation and payment principles of the RER Support Mechanism.[9] According to this regulation, the generation licenses given by EMRA to renewable power plants are accepted as RER Certificate during license period. RER Support Mechanism will be operated by the Turkish wholesale market operator, the Market Financial Settlement Centre (MFSC). The MFSC is obliged to take necessary measures in order to make the mechanism operational by 1 December 2011. Renewable power plants commissioned/will be commissioned between 18/05/2005 and 31/12/2015 and "*exempted generators*" can benefit from the mechanism for a period of 10 years starting from their commissioning date.

Figs. 5 and 6 show daily and monthly operation of RER Support Mechanism, respectively. In this mechanism, electricity generated by licensed renewable power plants and surplus energy exported to the grid by "*exempted generators*" are sold to suppliers by the MFSC on day-ahead market at corresponding hourly market prices. Based on meter readings and the FiTs, the MFSC calculates total cost of renewable portfolio (RER Total Amount) and invoices this cost to each supplier in proportion to their Payment Obligation Ratio, i.e. the amount of electricity sold by each supplier divided by the total amount of electricity sold by all suppliers in the country. The collected amount is then paid to renewable based generators subject to the mechanism in proportion to their share in renewable generation. The revenue collected from the sale of renewable energy on day-ahead market at market prices, i.e. RER Portfolio Income, is redistributed to the suppliers in proportion to their Payment Obligation Ratio. In this mechanism, no responsibility is put on to renewable generators for their imbalances that imbalance cost is also paid by suppliers.

With this mechanism, suppliers are indirectly obliged to purchase electricity that is generated from renewable sources while they are allowed to reflect the cost of renewable generation to their customers' invoice. Therefore, total cost of renewable generation does not make a direct burden on government budget, rather it is paid by all consumers within the country.

(iv) *Establishment of power plants in protected regions:* Establishment of renewable based power plants in environmentally sensitive areas are allowed provided that necessary permissions are obtained from the Ministry of Environment or regional conservatory board.
(v) *Reduced fees for land acquisation:* Same incentives provided by Energy Efficiency Law still apply but the scope of the incentive is expanded to renewable based plants commissioned before 31 December 2015 and the ones which were already in operation at the date of the enactment of the Amendment Law.
(vi) *Tax exemption:* Renewable based power plants are exempted from paying 1% Treasury share that is taken as specified by Additional Article 2 of the 29 June 2001 Law No. 4706 on Making Amendments to the Law on the Valuation of Immovable Properties Belonging to the Treasury and Value Added Tax.
(vii) *Special provisions for solar power*: Total installed capacity of RER Certified solar power plants that can be connected to the transmission network until 31 December 2013 is limited to 600 MW. After that date, the Council of Ministers is authorized to determine total installed capacity of solar generators to be connected to the transmission grid. The Amendment Law puts the responsibility on the Ministry of Energy to determine and publish the transformer centres to which solar power plants can be connected and their connection capacities within 6 months after the validity of the Law and each year until the end of 2015 after taking technical opinions of EIE and TEIAS. After 31 December 2015, the Ministry of Energy is required to determine and publish the transformer centres and their connection capacities each year, with the first being on 1 April 2014.

[9] The Regulation Regarding Certification and Supporting Renewable Energy Resources, published in the Official Gazette Date: 21 July 2011 No: 28001.

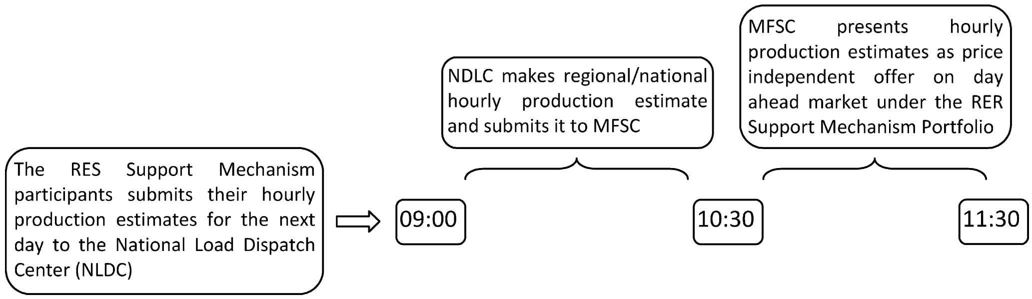


Fig. 5. Daily operation of RER support mechanism.

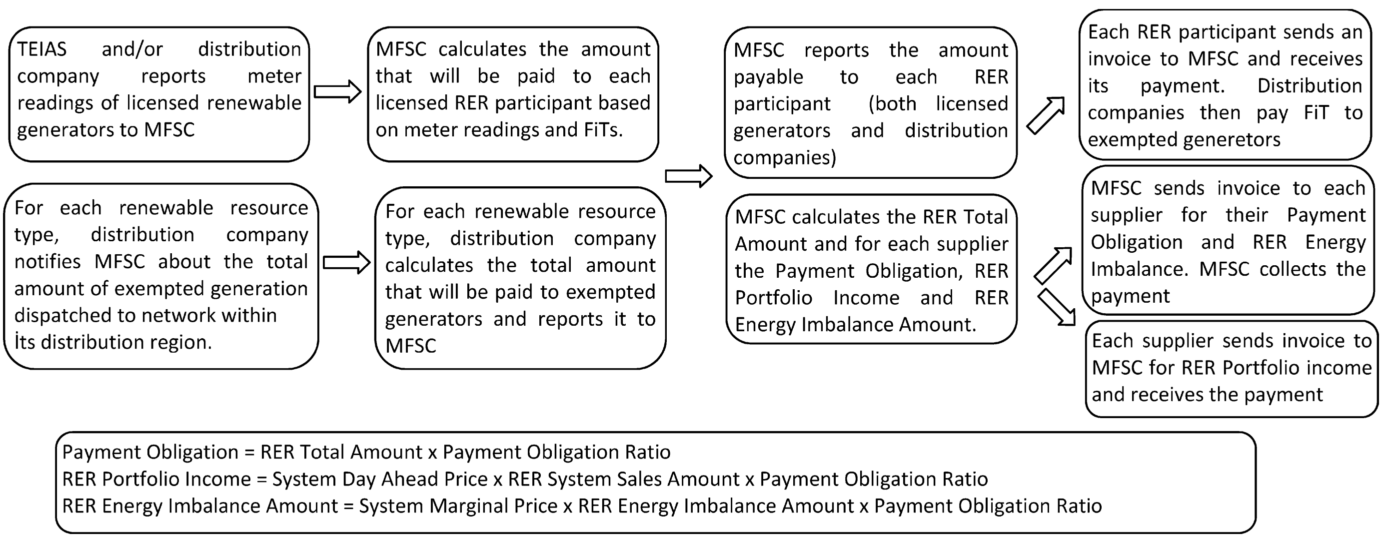


Fig. 6. Monthly opration of RER support mechanism.

The Amendment Law also obliges solar power plant license applicants to submit a measurement compliant with relevant standards during license application. If the legal owner applies for a generation license in order to develop a solar power plant on his/her own land, no other license application can be made for the same land. In case, there is more than one license application for the same area and/or transformer centre, TEIAS will organize a tender in order to determine the applicants to be connected to the system with a capacity equal to that of the announced capacity. The tender will be based on underbidding of solar FiT given in Table 5.

6. Evaluation of current incentives for solar power

Currently, solar power investors can benefit from the incentives provided by the License Regulation and the Amendment Law. New solar FiT introduced by the Amendment Law supports CSP, PV and hybrid power plants which generate solar energy with other non-renewable energy resources. Many investors think that Turkish solar FiT is not competitive enough to make the most costly renewable technology of solar favourable against other energy sources, particularly against natural gas. The solar tariff of 13.3 $cent/kWh plus local component bonus is considerably lower than the rates in many European countries. For comparison, current solar FiT in Germany, Spain and Italy are given in Tables 7–9 [44–46]. As it is seen, German, Italian and Spanish PV FiTs are almost three times higher than Turkish solar FiT. Setting FiT at a level that both reflects electricity generation cost and guarantees profitibility is the key element to be considered in designing an FiT policy [47]. In 2010, generation cost for large ground-mounted PV systems ranged from around 29 €cent/kWh in the north Europe to 15 €cent/kWh in

Table 7
German PV feed-in tariff in 2011.

Type	Capacity	Feed-in tariff (€/kWh)
Rooftop	<30 kW	0.287
	>30 kW < 100 kW	0.273
	>100 kW < 1000 kW	0.258
	>1000 kW	0.215
Ground-mounted	Conversion and sealed areas	0.221
	Commercial zones	0.211
	Crop land	n/a
Net metered	<30 kW and <30%	0.124
	<30 kW and >30%	0.167
	<100 kW and <30%	0.110
	<100 kW and >30%	0.153
	>30 kW < 500 kW and <30%	0.094
	>30 kW < 500 kW and >30%	0.139

Tariffs are valid for 20 years.
Tariffs decrease each year based on the amount of capacity installed during the previous year (corridor degression system).

Table 8
Spanish PV feed-in tariff in 2011.

Type	Feed-in tariff (€/kWh)
Rooftop & facades <20 kW	0.281
Rooftop & facades >20 kW <2 MW	0.198
Remainder (ground-mounted) < 10 MW	0.130

During 2011–2013, tariffs are valid for annual generation of maximum 1250 h for fixed installation, 1644 h for 1-axis tracking installation and 1707 h for 2-axis tracking installation. Any surplus generation should be sold at wholesale market or through bilateral contracts.

Table 9
Italian PV feed-in tariff in 2011 (€/kWh).

Peak capacity	Grid connection between 01/01/2011 and 30/04/2011		Grid connection between 01/05/2011 and 31/08/2011		Grid connection between 01/09/2011 and 31/12/2011	
	PV installed on buildings	Other PV systems	PV installed on buildings	Other PV systems	PV installed on buildings	Other PV systems
>1 kW <3 kW	0.402	0.362	0.391	0.347	0.380	0.333
>3 kW <20 kW	0.377	0.339	0.360	0.322	0.342	0.304
>20 kW <200 kW	0.358	0.321	0.341	0.309	0.323	0.285
>200 kW <1000 kW	0.355	0.314	0.335	0.303	0.314	0.266
>1000 kW <5000 kW	0.351	0.313	0.327	0.289	0.302	0.264
>5000 kW	0.333	0.297	0.311	0.275	0.287	0.251

Tariffs are valid for 20 years.
The feed-in tariff will be reduced by 6% in 2012 and 2013.

the south Europe [23] while Turkish solar industry estimates an average generation cost of minimum 18–20 €cent/kWh for Turkey [48]. In this respect, Turkish solar FiT of 13.3 $cent/kWh which is approximately equals to 10 €cent/kWh seems to be insufficient for a decent return on investment. Although local component bonus makes the situation better (approximately maximum tariff of 15 €cent/kWh for PV and 17 €cent/kWh for CSP with local component bonus), the bonus is valid for only the first five years of operation. Although, there has been a number of strong players in the domestic solar power industry, many local businesses has just started to manufacture solar power plant components [48]. Therefore, it is not clear yet at what extent the investors could procure components from domestic market and how easy the administrative procedures related to certification and inspection of domestic components would be. It would have been better if additional incentives for domestic components would have been valid for ten years in order to account for the development in domestic supplier industry.

The FiTs are guaranteed for a reasonably long period of time in order to ensure security of the investment for investors and manufacturers [47]. The FiT term is commonly determined such that income is guaranteed over the lifetime of the system, i.e. at least 15–20 years [23]. Turkish solar FiT is guaranteed for 10 years while European solar FiTs are generally guarenteed for a longer period, i.e. 20 years or more. Turkish solar industry calculates the return period as ten years if solar FiT is 18–20 €cent/kWh. Therefore, 10 years duration seems to be insufficient to pay back solar investments with an FiT of 13.3 $cent/kWh [49].

In many countries, solar FiTs are differentiated by system size and application type. Smaller PV systems in buildings are promoted through higher tariffs in Europe since residential PV systems are more expensive than large ground-mounted systems [23]. However, in Turkey, a fixed FiT is adapted for all solar applications. When Turkish residential electricity price of 12.2 €cent/kWh [50] in the first half of 2011 is considered, a higher solar FiT could have been adapted for residential applications in order to encourage the deployment of building integrated solar applications. Despite critizing level and duration of solar FiT, Turkish solar power industry supported the differentiation of FiTs with respect to generation cost of different renewable technologies rather than linking to wholesale rates. In 2010, Turkish average wholesale electricity price (TORETOSAF) was approximately equal to 8.53 $cent/kWh [51], which is lower than current solar FiT and not sufficient to attract solar investment.

The Turkish government utilizes the volume management strategy of introducing market and project size caps in order to limit the solar power market growth. The Amendment Law introduced a market cap of 600 MW until the end of 2013 while the License Regulation caps the capacity of individual solar power projects to maximum 50 MW. By introducing caps, government wants to limit the financial impact on ratepayers due to solar power entering into country's energy mix. The ability of current grid to accommodate high level of solar power and required improvements in the grid are also main concerns of the government in limiting Turkish solar power market. If 40–50 GW license application for solar power expected by Turkish solar industry [52] is concerned, 600 MW cap will be an important barrier for rapid expansion of solar power in Turkey.

7. Guidelines for solar power investors

Two important developments took place in August 2011, which were significant concerns to solar power investors. Firstly, the Ministry of Energy announced the transformer centres to which solar power plants can be connected until 31 December 2013. Secondly, the License Regulation was amended and installed capacity of individual solar power projects which will apply for license were capped at 50 MW. The investment period for solar power has officially started for private investors with these developments.

7.1. Where and how to invest for solar power in Turkey?

In the announcement, the Ministry determined 27 regions, 38 cities and 121 transformer centres to which solar power plants with a total capacity of 600 MW can be connected. Table 10 gives the regions, transformer centres and total connection capacity of the regions. These regions, having an annual solar radiation of more than 1650 kWh/m^2-year, are the most favourable areas for solar power generation in Turkey and are opened to investment by the Ministry at first. These regions also have high electiricity demand during summer, therefore solar power can particularly be used in these regions as peak shaving purposes. It is worth mentioning that the Ministry announced total connection capacity of transformation centres within each region rather than the individual connection capacity of each transformation centre. The connection capacity of each transformation centre will probably be announced during the tender process in case the total capacity of license applications for the same region exceeds the announced capacity.

Investors are required to develop their solar power plant on the land within these regions which are shown as bold in Fig. 7. Investors who wish to develop solar power plant should determine their power plant site considering announced regions, transformer capacities, grid distance and connection potential. Then, they should make solar measurement at the interested site for a certain duration. The measurement is required to be compliant with the Measurement Communiqué to be published by EMRA. License application date for solar power generation will be announced by EMRA and the potential investors will apply to EMRA together with their measurements and other required documents. The license applications will be finalized by EMRA based on the connection opinion of TEIAS, measurements and tender result in case the total capacity of license applicantions for the same region and/or transformer centre exceeds the announced capacity.

Table 10
Announced transformer centres for solar power connection until 31 December 2013.

Region	Transformer centre	Connection capacity (MW)
Konya 1	Aksehir, Alibeyhoyugu, Beysehir, Cumra, Konya3, Konya4, Ladik, Seydisehir	46
Konya 2	Altınekin, Eregli, Guneysınır, Karapınar, Kızoren	46
Van-Agrı	Baskale380, Engil, Ercis, Van, Van380	77
Antalya 1	Akorsan, Finike, Kas, Kemer, Korkuteli, Serbest Bolge	29
Antalya 2	Akseki, Alanya1, Alanya2, Alara, Gazipasa, Gundogdu, Serik, Varsak	29
Karaman	Ermenek, Karaman, Karaman OSB	38
Mersin	Akbelen, Anamur, Erdemli, Gezende HES, Mersin2, Mersin380, Tasucu	35
Kahramanmaras-Adıyaman	Adıyaman Golbası, Andırın, Cağlayan Havza, Dogankoy, Goksun, Kahramanmaras, Kılavuzlu, Narlı, Sır	27
Burdur	Bucak, Burdur, Tefenni	26
Nigde-Nevsehir-Aksaray	Bor, Derinkuyu, Misliova, Nigde2	26
Kayseri	Cinkur, Kayseri Kapasitor, Pınarbası, Sendiremeke, Taksan, Yesilhisar	25
Malatya-Adıyaman	Adıyaman, Darende, Hasancelebi, Malatya1, Malatya2, Malorsa	22
Hakkari	Bagıslı, Hakkari	21
Mugla-Aydın	Bozdogan, Dalaman, Datca, Fethiye, Marmaris, Mugla, Yatagan, Yenikoy	20
Isparta-Afyon	Barla, Egirdir, Isparta, Keciborlu, Kovada2, Kuleonu, Sarkikaraagac	18
Denizli	Acıpayam, Bozkurt, Tavas	18
Bitlis	Adilcevaz, Tatvan	16
Bingol-Tunceli	Bingol, Ozluce HES, Pulumur, Tunceli	11
Şırnak	PS-3, Sırnak, Uludere	11
Adana-Osmaniye	Bahce, Karaisalı, Osmaniye, Toroslar	9
Mus	Mus	9
Siirt-Batman-Mardin	Kızıltepe, Mardin, Siirt380, Siirt Cim, Siirt TM	9
Sivas	Kangal	9
Elazığ	Elazıg2, Hankendi, Hazar1, Hazar2, Maden	8
Sanlıurfa- Diyarbakır	Siverek	7
Erzurum	Erzurum1, Erzurum2, Hınıs	5
Erzincan	Erzincan, Erzincan OSB	3

It is very important to make solar measurement for potential investors although many investors may think that measurement is waste of time and money before having the license. Measurement is required in order to select investors who are serious in developing a solar power plant.

Having healthy solar measurement data would enable investors to assess the feasibility of their project. Solar power investors are given a preconstruction time of 16 months by EMRA. Having measurement and feasibility study in advance would enable investors to use preconstruction time more efficiently and start construction immediately after getting the license. The construction time given to investors is 16 months for solar power plants with a capacity of 10 MW or less while it is 24 months for solar power plants with a capacity between 10 MW and 50 MW. Also, many banks require investors to submit measurement results in order to assess financial viability of the project.

Land ownership may seem as an advantage for solar power projects since no other license application can be made for the same land. Turkish solar industry expects 40–50 GW license application for solar power [52]. Therefore, there will be a tender process and it will be more important to get capacity from the transformer centre in the tender rather than being the owner of the land. Measurement and feasibility studies based on these measurements would enable investors to make realistic offers in the tender. On the other hand, solar power projects having higher capacity would be more advantageous than smaller capacity projects in the tender process. Higher capacity projects can procure power plants components cheaper and therefore can bid generous offers in order to get the capacity from the transformer centre.

According to the Amendment Law, investors can develop solar power plants in environmentally sensitive areas and national parks provided that necessary permissions are obtained from relevant



Fig. 7. Announced regions for solar power connection until 31 December 2013.

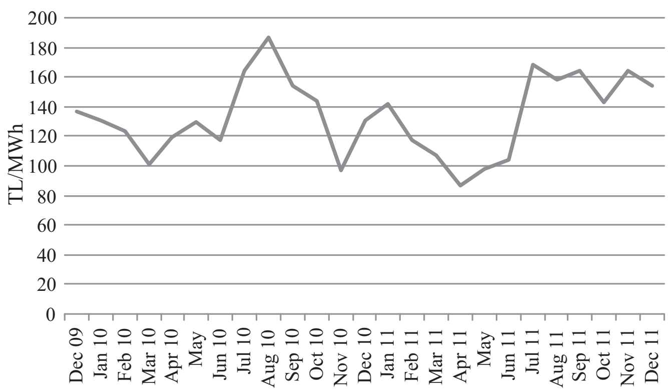


Fig. 8. System day-ahead price (SDAP) development in December 2009–December 2011 period.

authorities. Regions announced by the Ministry covers agricultural land, wetlands and shelter places which can be used to develop solar power plant. Developing solar power plants in such lands is highly probable to be objected by local people. In order to avoid court cases with local people and time consuming permission procedures, it would be better for investors to select unqualified land to develop their solar power projects.

7.2. Sale opportunities for solar power

Bilateral agreements, balancing and settlement market and RER Support Mechanism are three sales mediums in Turkish electricity market for electrical energy generated from solar power plants. Under bilateral agreements, solar power plants can sell generated electricity to TETAS, eligible customers and suppliers at negotiated price. In the balancing and settlement market, solar power plants can sell electricity at corresponding hourly prices developed in day-ahead market while they are subjected to imbalance costs which are settled at system marginal price developed in balancing power market. Therefore, solar power plants have to make accurate estimations of their hourly generation schedule that is submitted to market operator. Solar power plants can also sell generated electricity at FiT rate through RER Support Mechanism. If solar power plant license holder chooses to participate into this mechanism, it is obligatory to sell entire electricity generated under its license through the mechanism. License holders and distribution companies cannot sell the electrical energy generated within the scope of the mechanism under bilateral agreements.

Fig. 8 shows weighted average system day-ahead price (SDAP) development in the day-ahead planning market since December 2009 when balancing and settlement balancing market became operational [53]. In 2010, average SDAP was 122 TL/MWh while the highest SDAP was 420 TL/MWh at the time of annual peak. The SDAP was between 50 TL/MWh and 200 TL/MWh in about 8000 h in 2010 [54]. In addition, TORETOSAF was 140.7 TL/MWh in 2010 [32]. The RER Support Mechanism seems to be the most attractive sales medium for solar power plants since solar FiT (13.3 $cent/kWh which is approximately equal to 239 TL/MWh) is attractively higher than SDAP and TORETOSAF. Market prices are unpredictable and involve considerable risk with its associated imbalance costs. Indeed, solar power plants are not responsible for their imbalances and their monthly FiT payments are under the guarantee of MFSC in the RER Support Mechanism.

8. Conclusions

Turkey is an energy importing country with significantly high dependence on imported fossil fuels in supplying her continuously growing energy demand. High dependence on imports for energy poses significant risk for country's social, economic and environmental development. Turkey's huge solar energy resource can make significant contribution in supplying growing energy demand of the country. Utilization of solar energy resources can also enable the country to achieve the twin goals of reducing carbon emissions and increasing security of energy supplies since solar energy is an environmental friendly and secure domestic energy resource.

Despite having huge resource, Turkey has not utilized solar power yet due to lack of regulatory and financial support. Although it was a well known fact that solar power markets have developed by the help of government supported FiTs in many countries, Turkish government has taken only modest steps to promote investment in solar power until the end of 2010 when a new FiT policy was adapted.

The Renewable Energy Law No. 5346 was amended in December 2010 by the Amendment Law which set the legal framework for investment in Turkey's emerging solar power market. The Amendment Law introduced a guaranteed purchase price and a secure revenue collection mechanism for solar power investors. Domestic solar power industry is also encouraged to manufacture the components of solar power plants by the Amendment Law. As discussed in previous sections, incentives introduced by the Amendment Law have some shortcomings. However, the Amendment Law eliminated many uncertainties related to investment in Turkey's solar power market and gave momentum to many investors who appreciated Turkey's huge solar energy potential.

Currently, Turkey is an attractive virgin market for potential solar power investors when her huge solar energy potential is taken into consideration with her growing economy and energy demand. With recent policy developments in solar energy and the electricity market, Turkey offers a suitable investment environment for solar power. Although the Amendment Law was a major step for the realization of solar power projects, there has been substantial delay in the establishment of secondary regulation and the announcement for license application. The Amendment Law obliges solar power plant license applicants to submit a measurement compliant with relevant standards during license application. The measurement is required to be compliant with the Measurement Communiqué to be published by EMRA. However, the Measurement Communiqué was published at the end of January 2012, more than one year later the Amendment Law came into force. According to Measurement Communiqué, investors are required to make solar measuremet at least six months at particular solar power plant site and provide EMRA six month period measurement results together with one year's worth of experimental data apporoved by the TSMS. Therefore, potential investors will be given at least six months to make measurement and EMRA could not accept license applications before the second half of 2012. In addition, investors interest is expected to be at record levels when license applications will be accepted by EMRA. Potential investors are almost certain that there will be a tender process to get capacity from a transformer centre. Therefore, it would take some time for investors to get the license and start investment since evaluation of measurements and multiple applications for the same transformer centre, establishment of transformer connection limitations, tender process and finally licensing procedure will be a long process. Turkey has to speed up the regulatory process and finalize licensing procedure immediately in order to avoid further delays in harvesting country's huge solar energy potential since solar energy provides many opportunities to country's future.

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